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Phys 131L
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Laboratory 10: Conservation of Momentum

The law of conservation of momentum states that for a system of objects on which there is *no net external force*, the total momentum remains constant. The aim of this laboratory is to investigate this for collisions between two carts as illustrated in Fig. 1.

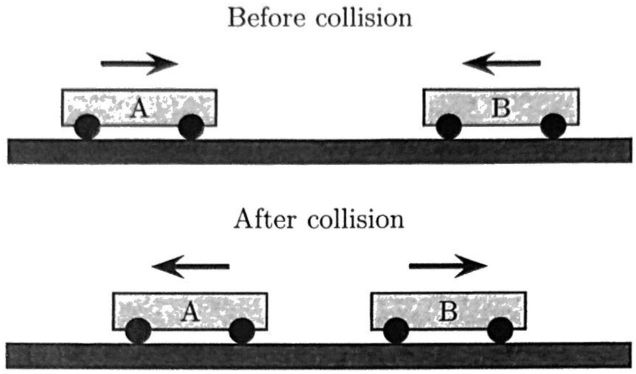

Figure 1: Colliding carts

The laboratory is equipped so that the velocity of any single cart can be measured at various instants. The momentum of any single cart at a given instant is

$$\vec{p} = m\vec{v}$$

where m is the mass of the cart and $\vec{v}$ is the velocity of the cart at the instant. The total momentum of the system at any instant is calculated by $\vec{p}_{\text{total}} = \vec{p}_{\text{A}} + \vec{p}_{\text{B}}$ where $\vec{p}_{\text{A}}$ is the momentum of cart A at that instant and $\vec{p}_{\text{B}}$ is the momentum of cart B at the same instant. Conservation of momentum implies that $\vec{p}_{\text{total before}} = \vec{p}_{\text{total after}}$. This laboratory exercise aims to verify this fact.

1 Experimental Set Up

The carts can produce various "collisions" and each requires the following set up.

a) Level the track.

b) The velocities of the carts will be determined using photogates. Each photogate is interrupted by a black strip on the piece of plexiglass mounted on the cart. DataStudio can read the time taken for the black strip to pass through the photogate. Adjust the photogates so that the 5 cm black strip triggers the photogate and the two carts are able to collide after the strip has passed each photogate.

c) Open DataStudio and connect each Photogate as follows:

   i) In the Experiment Setup check the "Time in Gate" box.

   ii) Drag both Time in Gate Ch 1 & 2 into the Table display option.

   For a collision in which the both carts pass through each gate twice, there will be four times. These are displayed in the "elapsed time" columns.

2 Elastic Collision

In an elastic collision the carts approach each other, collide and rebound as illustrated in Fig 2. To do this, orient the carts so that the ends containing the magnets face each other.

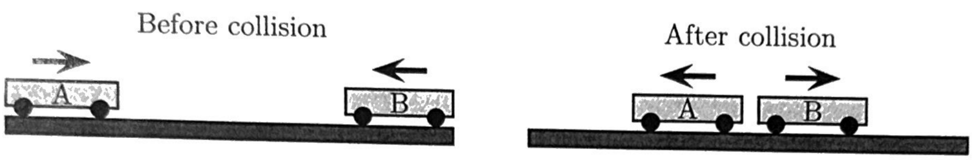

Figure 2: Elastic collision

a) Set up an elastic collision, with carts whose **masses are unequal**, and record the "elapsed time" for each cart *before and after* the collision.

b) Calculate the horizontal (or x) component of the total momentum before and after the collision. Is momentum conserved?

c) A reasonable measure of the discrepancy between the momenta before and after the collision is

$$\text{Percent error} := \frac{p_{\text{total after}} - p_{\text{total before}}}{\text{Magnitude of largest individual } p \text{ before}} 100$$

where $p_{\text{total before}}$ and $p_{\text{total after}}$ are the x-components of total momentum before and after the collision. Determine the percent error for this collision.

3 Inelastic Collision

In an inelastic collision one cart approaches a stationary cart and these adhere as illustrated in Fig 3. To do this, orient the carts so that the velcro ends face each other.

Figure 3: Inelastic collision

a) Set up an inelastic collision with the moving cart having about double the mass of the cart at rest. Determine the velocities *before and after* the collision.

b) Calculate the horizontal component of the total momentum before and after the collision. Is momentum conserved?

c) Determine the discrepancy between the momenta before and after the collision using

$$\text{Percent error} := \frac{p_{\text{total after}} - p_{\text{total before}}}{|p_{\text{total before}}|} 100.$$

4 Explosion

In an "explosion" both carts are held at rest against each other and the plunger is released as illustrated in Fig 4.

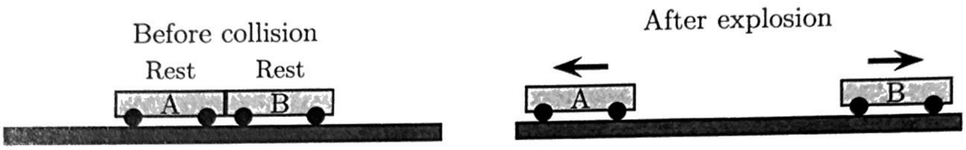

Figure 4: "Explosion"

a) Set up an "explosion" and determine the the velocities *before and after* the event.

b) Calculate the horizontal component of the total momentum before and after. Is momentum conserved?

c) Determine the discrepancy between the momenta before and after the explosion using

$$\text{Percent error} := \frac{p_{\text{total after}} - p_{\text{total before}}}{\text{Magnitude of largest individual } p \text{ after}} 100.$$

5 Conclusion

a) What do these experiments establish?

b) Explain any discrepancies between your observations and the theoretical predictions.

6 Exercises

a) A cart of mass m_1 moving to the right collides with a cart of mass m_2 that is at rest. If m_2 is significantly larger than m_1 then several scenarios are possible. In one scenario the cart on the left rebounds as illustrated in Fig. 5.

Figure 5: Rebound

In another scenario the cart on the left is at rest after the collision as illustrated in Fig. 6.

Figure 6: No rebound

In which scenario does the cart on the right move with greater velocity, assuming that the initial velocity of the cart on the left is the same? Explain your answer.

b) Two carts of different masses are initially held together and at rest. One cart has mass m_1 and the other mass $m_2 = \frac{1}{2}m_1$. A spring release plunger on the carts triggered, causing the carts to move apart. Which cart moves with greater speed after the plunger has been triggered? Explain your answer.

c) Two carts are held together. The cart on the left has mass m_1 and that on the right mass $m_2 = \frac{1}{2}m_1$. They are set into motion so that their speed is $4\,\mathrm{m/s}$ to the right as illustrated in Fig 7.

Figure 7: Carts initially together

After the plunger is triggered the cart on the right moves right with speed $6\,\mathrm{m/s}$. Determine the speed and direction of motion of the cart on the left after the plunger is triggered.

2 Elastic collision

a.

Cart A

$M = 515\ g$

Ellapsed time ① 0.0751 S

0.1225 S

Cart B

$M = 524\ g$

Ellapse time ② 0.0849

0.1203

Before A 0.0751S

After A 0.1225S

Before B 0.0849 S

After B 0,1203 S

D= 0.05 m

Before $v = 0.67\ m/s$

After $v = -0.41\ m/s$

$m = 0.515\ Kg$

$P = mv$

Before $P = 0.515\ Kg(0.67 m/s)$ ✓

$P = 0.35\ Kg \cdot m/s$ ✓

Before $v = -0.59\ m/s$

After $v = 0.42\ m/s$

$m = 0.524\ Kg$

$P = mv$

Before $P = 0.524\ Kg(-0.59\ m/s)$ ✓

$P = -0.31\ Kg \cdot m/s$ ✓

After $P = 0.515\ Kg(-0.41 m/s)$ ✓

$P = -0.21\ Kg \cdot m/s$ ✓

$P = 0.524\ Kg(0.42\ m/s)$ ✓

$P = 0.22\ Kg \cdot m/s$ ✓

b.) Before

$0.35\ Kg \cdot m/s - 0.31\ Kg \cdot m/s = 0.04\ Kg \cdot m/s$ ✓ B

After

$-0.21\ Kg \cdot m/s + 0.22\ Kg \cdot m/s = 0.01\ m/s$ ✓ A

Momentum is conserved

C.) $\left| \frac{0.01\ Kg \cdot m/s - 0.04\ Kg \cdot m/s}{0.35\ Kg \cdot m/s} \right| \times 100 = \boxed{8.6\%}$ ✓

3 Inelastic

b.) Cart A

$M = 1.015$ Kg

Ellapsed Time

Before = 0s After = 0.1017s

Mass of all

$V_i = \frac{0.05m}{0.1017} = 0.49$ m/s ✓

$M_A = 1.015$ Kg

Cart B

$M = 0.524$ kg

Ellapsed Time

Before = 0s After = 0.175 ✓

$V_f = \frac{0.05m}{0.175} = 0.29$ m/s ✓

$$P_i = M_A V_A + M_B V_B$$

$$P_i = M_A V_A$$

$$P_i = M_A V_A$$
$$= 1.015 \text{ Kg} (0.49 \text{ m/s})$$ ✓
$$P_i = 0.50 \text{ Kg} \cdot \text{m/s}$$ ✓

$$P_F = V_F (M_A + M_B)$$ ✓
$$= 0.29 \text{ m/s} (1.539 \text{ Kg})$$
$$P_F = 0.45 \text{ Kg} \cdot \text{m/s}$$ ✓

$$\left| \frac{0.45 \text{ Kg} \cdot \text{m/s} - 0.50 \text{ Kg} \cdot \text{m/s}}{0.50 \text{ Kg} \cdot \text{m/s}} \right| \times 100 = \boxed{10\%}$$ ✓

Since we are negating air resistance and friction momentum is conserved.

C.) $\boxed{10\%}$

4 Explosion

b.) Cart A

$M = 0.515$ Kg

Ellapsed time

Before = 0s After = 0.1422 ✓

$V = \frac{0.05m}{0.1422s} = -0.35$ m/s ✓

$P = 0.515 \text{ Kg} (-0.35 \text{ m/s})$ ✓

$P = -0.18$ Kg·m/s ✓

Cart B

$M = 0.525$ kg

Ellapsed time

Before = 0s After = 0.1676

$V = \frac{0.05m}{0.1676} = 0.3$ m/s

$P = 0.525 \text{ kg} (0.3 \text{ m/s})$ ✓

$P = 0.1575$ Kg·m/s ✓

c.) $\left| \frac{0.0225 \ kg \cdot m/s}{0.18 \ kg \cdot m/s} \right| \times 100 = 12.5\%$

12.5 %

5 conclusion

a.) This experiment establishes that negating air resistance and friction, momentum is always conserved.

b.) The discrepancies in this experiment would be user error, the track could be not 100 % level, the greater the mass the greater the friction force and the greater air resistance. Theoretically there would be no friction or drag.

6 Exercises

a.) In scenario 1 the momentum isn't completely transformed into positive/forward to the right momentum where as scenario 2 the momentum is all positive after the collision. Therefore scenario 2 should have a greater velocity.

b.) ~~M~~ m_1 would have the greater velocity because it has half the mass and the same force being acted on it as M_2, so the velocity of m_1 would be greater.

c.) $m_1 + m_2 = \frac{3}{2}$

$(m_1 + m_2)4 =$

$(\frac{3}{2}m_1)4 \ m/s =$ Before

$\frac{1}{2}m_1(6m/s) + m_1 v$

$6m/s \, m_1 = m_1(3m/s + v)$

$6 \ m/s = 3m/s + v$

$V = 3 \ m/s$

$V = 3 \ m/s$

Direction? -1/2